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# Watering Lima's Urban Desert: Sustaining the Flow

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## Introduction

As cities across the developing world grow faster than ever, the ability of governments to provide access to basic services becomes increasingly difficult. Over the past two decades, Peru has experienced mass migration from rural areas to urban centers and to Lima, in particular, with one of the highest rates of population growth among Latin American cities (Ioris, "The Persistent Water Problems…," p. 336). Lima has a population of approximately nine million and a growth rate of 1.5 percent per year (Eisenberg et al., p. 118). This growth has led to the rise of shantytowns around Lima, peri-urban communities that experience myriad social issues and inequalities. The municipal government has struggled to provide its inhabitants with access to clean water and sanitation in the shantytowns for decades.

Migrants come to Lima looking for jobs and a better quality of life, but the city is not prepared for this influx of people (Ruiz Rosado, p. 279). As the municipality struggles to incorporate this new population into the city, jobs and housing opportunities dwindle, resulting in high rates of unemployment and poor access to basic services like water and sanitation (Ruiz Rosado, p. 279). Because these settlements are often built in steep areas that lack paved roads, delivery of services is challenging (Ruiz Rosado, p. 279). This uncontrolled urbanization has also contributed to biodiversity loss and pollution, while increasing climate vulnerability (Eisenberg et al., p. 20). The United Nations considers a region water scarce if each inhabitant has less than 1 million liters of water per year; in Lima there are only 125,000 liters available per inhabitant per year ("Study of Water Risks…," p. 14). Clearly, Lima is a water-scarce city, and it faces additional problems pertaining to wastewater treatment, water quality, and equity among classes.

The Lima Potable Water and Sewer System Service in Peru (SEDAPAL) is the state-owned water utility serving Lima and the neighboring district of Callao that provides water and sanitation services to Lima residents (Karla et al., p. 1). The National Superintendence of Sanitation Services (SUNASS) operates on the national level and oversees SEDAPAL's activity (Karla et al., p. 1). SEDAPAL is responsible for operating the water and wastewater network throughout Lima, which involves capturing water from rivers, providing purification treatment, and collecting and treating wastewater through the sewage system ("Environmental Engagement in Water…," p. 6). There are a variety of other local, national, and international organizations that influence water resource management in Lima, such as Aquafondo[1] and the Ministry of Housing, Construction and Sanitation; but because there are so many institutions involved, I focus solely on SEDAPAL's work and projects for the purposes of this article.

In this article, I identify and evaluate what I believe are the main problems Lima faces regarding water and sanitation: scarcity, wastewater disposal and treatment, quality, and equity. I begin by outlining the different problems Lima faces pertaining to water supply. Then I discuss SEDAPAL's two different approaches to the problems: gray infrastructure[2] and green infrastructure (GI). I outline how SEDAPAL plans to address these problems in coming years through gray infrastructure projects and also the important investments it is making in GI. I also discuss the importance of GI and conclude with my thoughts on SEDAPAL's plans and actions.

## Problems with Water and Sanitation

One of Peru's major water problems is its limited supply. Seventy percent of Peru's population resides on the semi-arid coast where only two percent of the nation's water reserves are located, creating clear problems for water security in coastal cities like Lima (Ioris, "The Geography of Multiple…," p. 612). At present, water demand in Lima is 85.5 billion liters, and SEDAPAL is only able to meet 90.4 percent of the demand (Karla et al., p. 17). During the dry summer months, due to lack of rainfall and high demand, there is an average deficit of about 3050 liters per second (Gammie and De Bievre, p. 2). This limited supply leaves many citizens without a reliable water source.

Water usage rates within the city vary across income groups and geographical locations. On average, a single resident uses 170 liters of water a day (Miranda Sara and Baud, p. 506). However, the consumption rate is not equally distributed throughout the population. Consumption rates can be as low as 25 liters per person per day in low-income neighborhoods and as high as 460 liters in high-income ones (Miranda Sara and Baud, p. 506). Furthermore, impoverished communities generally have fewer drinking water connections, which forces residents to pay for more expensive water from tanker trucks. As a result, they need to be more frugal with the water they receive and often can afford only small amounts.

Drinking water in Lima comes from several sources. Residents of Lima depend primarily on the Rímac, Chillón, and Lurín rivers as well as on groundwater to meet their water needs (Eisenberg et al., p. 35). Additionally, SEDAPAL operates large infrastructure projects, including dams and tunnels that catch glacial melt from the Andes and transport it to Lima (Castro et al., p. 4). Unfortunately, the current water supply system has been unable to provide universal access to safe, clean drinking water, with about 1.5 million residents without access in 2015 ("Thirsty Lima…"). Serious efforts must be made to reduce this number and provide all citizens with potable water.

Already inadequate, Lima's water supply system faces major threats, including population growth, decreased precipitation, overexploitation of groundwater, and decreased glacial melt. An expected rapidly expanding population will put additional pressure on an already limited water supply. With an average yearly precipitation rate of only 9 millimeters

[1]Aquafondo is the Lima Water Fund that finances water conservation projects. Its members include the Nature Conservancy, Grupo GEA, Fondo de las Américas, the Catholic University of Peru, the Peruvian Society of Environmental Law, and the Union of Peruvian Breweries Backus and Johnston.

[2]Gray infrastructure: built infrastructure, ranging from simple detention ponds to complex and expensive reservoirs (Eisenberg et al., p. 54).

(Castro et al., p. 3), seasonal rainfall is unable to meet the city's water demand (Eisenberg et al., p. 86). Moreover, precipitation rates are predicted to decrease and the frequency and severity of droughts to increase (Karla et al., p 3). In the next few years, experts expect a six percent decrease in rainfall but as high as a 13 percent reduction is possible ("Study of Water Risks …," p. 4). During the dry season, when the rivers are so low that the Rímac River is nearly dry by the time it meets the ocean (Roman et al., p. 3), the city depends largely on groundwater supply (Eisenberg et al., p. 35). Because of high rates of groundwater extraction, saltwater intrusion threatens the quality of the groundwater supply (Eisenberg et al., p. 35). Lima also relies on Andean glacial melt into the rivers (Karla et al., p. 2). Climate change has had an effect here, and over the past 40 years the amount of glacial melt feeding the Rímac River has decreased by 90 percent (Karla et al., p. 2). Furthermore, Lima's water supply would be seriously jeopardized if any damage should happen to the tunnel bringing water from the Andes to Lima (Castro et al., p. 4). In summary, as Lima struggles to provide water to its ever-growing population and with experts expecting more severe and frequent droughts in the future due to the negative effects of climate change, water scarcity problems will only intensify (Karla et al., p. 3).

In addition to the water supply, SEDAPAL oversees Lima's public sewage system. Metropolitan Lima as a whole receives approximately 1.2 billion liters of sewage a day, with each resident generating around 145 liters of sewage water ("Environmental Engagement in Water…," p. 16). There is a total of 41 wastewater treatment plants (WWTPs) in the city run by SEDAPAL, the Lima Metropolitan Municipality, district municipalities, and public and private institutions (Eisenberg et al., p. 38; Cavallini, 2011, p. 14), with SEDAPAL's 18 plants managing 93 percent of wastewater collection (Cavallini, 2011, p. 16). Although there are a significant number of WWTPs operating, gaps remain. It is estimated that 1.3 million people still lack access to adequate sanitation in Lima ("Study Tour from Peru to Brazil…," p. 1), with approximately 330,000 households remaining unconnected to the public sewerage system. This, of course, constitutes a potential public health threat (Eisenberg et al., p. 132).

Although 93 percent of wastewater is collected by SEDAPAL, this amount exceeds the capacity of the WWTPs and places a strain on them because they now work above their capacity ("Environmental Engagement in Water…," p. 4). In fact, only 15 percent of wastewater collected is actually treated in one of the WWTPs overseen by SEDAPAL (Castro et al., p. 5). Essentially, seven percent of total wastewater is not collected, and 85 percent of collected wastewater receives no treatment. Therefore, large amounts of untreated wastewater are released into rivers, lakes, and the ocean, causing high levels of pollution (Castro et al., p. 5). Additionally, only 17 percent of the limited amounts of wastewater that is treated is reused in the city. Because such small amounts of treated wastewater are reused, potable water is widely used for irrigation (Eisenberg et al., p. 86). Altogether these figures indicate a significant amount of wasted water and hence a lost opportunity regarding water supply (Eisenberg et al., p. 86).

Despite attempts at wastewater treatment, high levels of pollution continue to be a major contributing factor to low wastewater reuse (Eisenberg et al., p. 141). Treated wastewater is typically used for irrigation, but at times the water quality can be so poor that it is not acceptable for this application (Eisenberg et al., p. 141). In 2011, SUNASS conducted a study that revealed that only four of SEDAPAL's 18 WWTPs produced treated wastewater that met water quality requirements for irrigation of green spaces, let alone for higher-end usage like drinking or bathing (Eisenberg et al., p. 226). In some cases, people reuse tainted water for agricultural activities, which poses a threat to public health. A study conducted by the Program of Urban Harvest of the International Potato Center and the Community of Madrid discovered that the water used for irrigation in areas of the Eastern Cone of Lima had high levels of fecal parasites and coliform (Cavallini, 2016, p. 28). The levels of fecal coliform were 5,000 times above minimum quality standards for agricultural water use (Cavallini, 2016, p. 28). Due to the outrageously high concentrations of fecal coliform, about 30 percent of the vegetables produced were deemed unfit for human consumption (Cavallini, 2016, p. 28). Reuse of wastewater can be a significant way to conserve water; the system must be improved so such practices do not threaten people's health.

A major goal is to expand the number of household drinking water connections in the city. If this is accomplished, then the issue of wastewater must also be addressed. Currently, households connected to the drinking water supply but not to the sewage system dump their black water (ie, waste from toilets) into septic tanks, rivers, or irrigation channels (Eisenberg et al., p. 240). Although there is nothing inherently wrong with septic tanks unless they are poorly managed, the dumping of black water into rivers and irrigation channels is concerning. Houses not connected to the water supply do not generate black water but rather get rid of their feces in latrines or dry toilets (Eisenberg et al., p. 235). Eventually, these unconnected houses will be connected to the water supply and when they are they will contribute to the quantity of black water waste emitted into waterways (Eisenberg et al., p. 240). When more households receive water connections, the city will have to build additional sewer lines or face a likely increase in pollution levels. To avoid such an outcome, no new water supply connections without concomitant sewage connections should be installed.

## Peri-urban Communities and Equity Issues

Water and sanitation services are unequally distributed throughout Lima. Households that are not connected to the public water and sanitation system are typically concentrated in the newer and constantly growing impoverished peri-urban communities (Eisenberg et al., p. 132). These peri-urban neighborhoods are expanding at rates of between 50 percent and 240 percent annually; meanwhile, populations in older and more established communities have largely remained the same (Eisenberg et al., p. 112). Living conditions in these new neighborhoods are precarious, because they are often located on sandy hills, making water transportation extremely difficult (Ioris, 2015, p. 1167). A combination of rapid population growth and geographical location, as well as a lack of coordination with urban planners, makes service provision in the urban periphery challenging.

Water scarcity reflects and perpetuates the inequality and discrimination that are widespread in Lima (Ioris, "The Geography of Multiple…," p. 614). Neighborhoods that lack access to water tend to be impoverished and are often made up of large migrant and indigenous populations who have little power to demand water and influence politics (Ioris, "The Geography of Multiple…," p. 614; Ioris, 2016, p. 35). People in these communities must find water from different sources when not connected to the public supply. Their options are limited to small-scale providers: tanker trucks, private wells, springs, streams, and rivers ("Evaluation of Small-Scale Providers…," p. 5). Unfortunately, these are often unreliable and expensive options. According to SUNASS, a cubic meter of water from the public water network costs approximately $0.30; meanwhile, buying one cubic meter of water from a truck can cost more than $4.00, or 12 times more. To make matters worse, the water provided by these trucks is often dirty and polluted.

There is a clear relationship between income and access to the public water supply. High-income and middle-income municipalities achieve 99.8 percent and 77.9 percent coverage, respectively (Ioris, 2016, p. 130). Meanwhile, low-income areas only have a 68.1 percent coverage rate (Ioris, 2016, p. 130). Furthermore, in high-income neighborhoods, where access to water tends to be greater and more reliable, waste is also more common. Meanwhile, lower-income areas experience shortages daily; those that do receive piped water only do so for a few hours a day (Ioris, 2016, p. 134). Thus, it is residents who lack access to public water and sanitation who pay the most for what they do have and use ("Brazil, Colombia and Peru…").

Although past projects to improve Lima's water problems have yielded some improvements, significant issues remain. Many of these efforts have involved investing more money in infrastructure, raising water prices, and developing more public-private partnerships. In response to depleting groundwater levels, Lima has also passed laws to reduce extraction of groundwater. However, scarcity persists, leading to mistrust between SEDAPAL and low-income residents. Investments in infrastructure have been successful in improving water supply and sanitation statistics overall, but low-income residents continue to face problems involving reliability of services and scarcity (Ioris, "The Geography of Multiple…," pp. 619–20).

## The Future of Water and Sanitation in Lima

There is strong political support for water and sanitation projects. The president, Pedro Pablo Kuczynski, made water and sanitation issues a central part of his campaign and now pledges to provide water and sanitation to all Peruvians within the next five years ("Plan of the Government…," p. 9). Over the past few years, Peru has made progress on environmental and water-related issues, but problems remain. There are many institutions working on water and sanitation issues and their projects often overlap, creating problems related to inefficiency and coordination (Eisenberg et al., p. 109). Although water, sanitation, and urbanization issues cross many ministries and agencies, traditionally policy development in this area has been top-down and sectoral (Castro et al., p. 29). Inter-agency coordination must be improved to make progress on water and sanitation issues in Lima ("National Strategy for Improvement…," p. 17). Although there are a number of agencies working on water and sanitation issues, SEDAPAL, as the local water utility, is primarily responsible for solving these problems.

### SEDAPAL's Master Plan

SEDAPAL recently developed a multi-billion-dollar Master Plan to address water and sanitation needs in Lima. This Master Plan focuses on adapting Lima's water and sewage system to expected future increases in demand and potential decreases in supply due to climate change (Karla et al., p. 2). The plan encompasses the period from 2015 through 2040 and consists of 12 extensive gray infrastructure investment projects, including reservoirs, water treatment plants, desalination plants, and tunnels, altogether costing $2.3 billion. Since the plan's finalization, additional projects at a cost of $400 million are also being considered (Karla et al., p. 1). To increase the city's water supply, projects that SEDAPAL is undertaking include expanding existing reservoirs, constructing new ones, and exploring more unconventional methods like desalination ("Master Plan…," p. 47). Additionally, SEDAPAL acknowledges that, moving forward, proper management of aquifers is essential ("Master Plan…," pp. 83, 86). During the dry season, aquifers are a critical source of water, and it is important that they be used in a sustainable manner ("Master Plan…," pp. 83, 86). Previously, SEDAPAL overexploited aquifers, but recently it has invested in aquifer recharge projects to manage and place less stress on aquifers and prevent overexploitation ("Master Plan…," pp. 83, 86). Ultimately, to meet future water demands, SEDAPAL is relying largely on gray infrastructure projects.

As noted, population growth places a significant amount of pressure on the available water supply. As the city continues to grow, SEDAPAL is making efforts to incorporate new peri-urban areas into the system ("Master Plan…," p. 224). Such incorporation will not be an easy task and likely result in increased service demands, additional sewerage loads on WWTPs, and higher levels of water consumption. As previously discussed, to address problems regarding water, SEDAPAL frequently implements new supply-oriented infrastructure projects, although this approach may not be able to adequately address Lima's growing problems.

Poor water quality is a significant problem for the city, and it has not gone unnoticed by SEDAPAL. SEDAPAL has identified the high levels of water contamination in rivers from mining, industrial, and agricultural activities as a major impediment to supplying high-quality drinking water ("Master Plan…," p. 47). In the past, it has implemented water treatment plants to combat this; however, the problem persists ("Master Plan…," p. 47). Although poor treatment of wastewater contributes to low-quality drinking water, SEDAPAL is optimistic that with the construction of additional WWTPs it can reach 100 percent wastewater collection and treatment within its jurisdiction. Recently, the level of wastewater collection was around 93 percent, although wastewater treatment has only been about 15 percent. Although 100 percent wastewater collection would be desirable, the more significant advancement would be to achieve 100 percent water treatment. Efforts by SEDAPAL have not been very successful. In the past, SEDAPAL has been unable to achieve 100 percent coverage through gray infrastructure projects; because of this, it should continue to explore other options, specifically GI, as I explain in the following section ("Master Plan…," pp. 229, 234, 240, 243).

### Green Infrastructure

In addition to the Master Plan,[3] SEDAPAL is investing funds in GI. GI includes information and ideas from a variety of fields, ranging from biology and landscape ecology to city planning and economics (Eisenberg et al., pp. 51–52). GI uses natural and semi-natural environments to improve the health and resiliency of communities through preservation, restoration, or replication of natural water processes (Eisenberg et al., p. 51; "What is Green Infrastructure?"). Additionally, GI projects serve several different functions; because of this, a single GI project can produce a variety of benefits for the community. Because of its multi-faceted nature, GI can greatly improve the environment and the health of Lima's communities, while also promoting economic growth and ultimately building a stronger, more resilient city (Eisenberg et al., p. 52). SEDAPAL leads the Latin American region on GI-related projects. In June 2015, SUNASS approved a regulatory framework, the first of its kind in Latin America, that requires water utility companies to incorporate ecosystem services into water tariffs. The funds from these tariffs are then allocated to GI projects. Overall, Lima intends to devote one percent of its water tariffs to GI ("Lima's Master Plan…"). Currently, funds from this policy amount to $5 million, and this number is expected to grow to $30 million by 2020 ("Lima's Master Plan…"). Although these numbers are small in comparison to gray infrastructure investments, they signal an important step in the right direction.

Most importantly, SEDAPAL is developing a GI Master Plan. This comes in response to a recent drought, followed by heavy rainfall that resulted in landslides killing 20 people and overflowing rivers that obstructed treatment plants with debris and rocks and left many without water. The GI Master Plan would be the first of its kind; because SEDAPAL is also reshaping the city's broader overall Master Plan to fit the new president's vision, it is trying to integrate its GI Master Plan into the overall Master Plan, which is expected to be revised by the end of 2017. SEDAPAL aims to use this GI Master Plan to develop a strategy for the next 30 years to preserve grassland and wetland ecosystems upstream and to prevent erosion, because it reduces the land's ability to absorb water during rainfall and then discharge it during dry seasons. Additionally, SEDAPAL plans to use GI to protect existing gray infrastructure from events including landslides. SEDAPAL is still in the early stages of planning and, at the time of this writing, has yet to release any immediate plans.

I discuss a few projects that SEDAPAL is reviewing. I believe it is critical that SEDAPAL undertake these projects to address the city's water and sanitation problems. The nonprofit Forest Trends identified and evaluated four measures that can be implemented in Lima to improve water resources: exclusion of animals from natural grasslands, rotational grazing on natural grasslands, hydrological restoration of drained wetlands, and restoration of pre-Incan canals known as *amunas* (Gammie and De Bievre, pp. 7–8). For both animal exclusion and rotational grazing, animals are removed from the land to allow for restoration of the surrounding ecosystem. This ultimately improves water flow and filtration. Meanwhile, hydrological restoration involves closing trenches that drain water for animals grazing

[3]The Master Plan was released in June 2014; meanwhile, SEDAPAL's plans to undertake more GI projects were not announced until April 2015. Therefore, the timing of these plans may be what has prevented SEDAPAL from including GI in the Master Plan.

to increase surface water storage. Finally, amuna restoration entails repairing the walls of canals that distribute water away from streams so that the groundwater can be re-infiltrated and used during the dry season. Best estimates are that these interventions could produce 58.2 million cubic meters of water a year, which alone would offset the dry season deficit of 43 million cubic meters (Gammie and De Bievre, p. 13). Clearly GI projects can yield huge benefits; if they were in fact able to cover the dry season deficit, the consequences for Lima would be enormous.

Promotion of green spaces as a form of GI also helps improve social and economic conditions in peri-urban neighborhoods (Eisenberg et al., p. 72). Unfortunately, most green spaces in Lima are located in high-income areas. Green spaces, such as parks and gardens, can improve individuals' mental health and promote social cohesion because they offer safe spaces for community members to socialize and relax. Furthermore, incorporation of multifunctional open spaces can increase economic opportunities in informal settlements. Green spaces can treat and filter water; as a result, higher-quality water can be used for agriculture without threatening public health (Roman et al., p. 2).

The nongovernmental organization Urban Harvest successfully used GI to treat and reuse wastewater for agriculture in Lima. It implemented a project in eastern Lima, where 48 percent of inhabitants are part-time farmers. At the time of the project, the population in this area was rapidly growing, with a new house built every day. Although more land was used for housing, vegetable farming was still popular. However, the water canals were polluted and jeopardized the quality of the crops as well as public health. Urban Harvest executed several projects to manage the pollution. One project used settling ponds as a water filtration system. The water then became suitable for irrigation and met the national water quality standards. This program was successful not only because of the GI projects but also because of the trusting and mutually beneficial working relationship that Urban Harvest built with the local community (Roman et al., pp. 5–6).

Generally, when faced with water and sanitation problems, Latin American and Caribbean countries devote funds to large infrastructure projects (Echavarria et al., p. ii). Now, however, Lima is implementing a more holistic approach to providing water and sanitation services to its residents, one recognizing the value of conservation and preventative solutions (Echavarria et al., p. ii). Lima continues to invest most of its funds in heavily technical infrastructure projects, but investments in GI and the construction of a GI Master Plan represent a huge step in the right direction (Echavarria et al., p. 16). Although there are many reasons to be optimistic about these groundbreaking plans, it is important to see how they are implemented and to gauge their levels of success before reaching a final judgment.

## Conclusion

SEDAPAL appears to be taking important steps toward the universal provision of water and sanitation in Lima, while continuing to face complex challenges—it is important when addressing these challenges that it not neglect low-income residents. The government should provide equal access to all citizens, regardless of income, ethnicity, and social class. SEDAPAL must make providing services to peri-urban communities its main priority. Water provision in these neighborhoods also needs to be in conjunction with sewage connections, to manage pollution problems related to wastewater. Additionally, to accomplish this, it is crucial that SEDAPAL work directly with communities and consider their needs and experiences when constructing plans. In doing so, SEDAPAL can gain the communities' trust and establish a mutually beneficial relationship.

Beyond developing relationships with communities, SEDAPAL must also effectively coordinate and collaborate with other agencies. Water provision is complicated and involves several different actors, including urban planners, local and national governments, lawyers, nongovernmental organizations, financial institutions, and many others (Eisenberg et al., p. 44). Factors including population growth and housing greatly affect SEDAPAL's ability to provide services; although

SEDAPAL is not responsible for addressing those issues, it must work with agencies that are. These actors must work together to efficiently construct an integrated strategy; otherwise time and money will be wasted on conflicting projects.

In the past, when faced with water and sanitation problems, SEDAPAL relied heavily on technological solutions involving large investments in gray infrastructure projects. However, SEDAPAL is adapting its previous strategy to include GI. It is clear that with the impending threats the city faces, business as usual will no longer suffice. SEDAPAL is now implementing a new approach, specifically one that takes a more integrative look at the city. GI projects are multi-faceted and holistic in nature; as SEDAPAL continues to explore them, they should become an essential part of SEDAPAL's future plans. It is crucial that SEDAPAL follow through on its GI Master Plan and place as much importance on GI as on gray infrastructure. Over the next few years, as SEDAPAL releases its GI plans, it is important that success of the project be evaluated and that SEDAPAL be held accountable to investing in these types of projects in the future.

The future of water in Lima remains uncertain. However, institutions within and outside the city seem strongly invested in ensuring access to water and sanitation for all residents. I believe that as long as the government remains committed to the cause and that the funding is available, SEDAPAL should continue to invest and emphasize integrated water management approaches, particularly in shantytowns. If carried out thoughtfully and in an equitable manner, Lima will be able to secure water for all in coming years.

# REFERENCES


"Brazil, Colombia and Peru are among the Countries of the world with the most water." World Bank. March 10, 2015. www.worldbank.org/en/news/feature/2015/03/10/brasil-colombia-peru-paises-mas-agua-tienen-en-el-mundo. Accessed August 22, 2016.

Castro, Cecilia, Gunther Merzthal, and René van Veenhuizen. "Integrated Urban Water Management in Lima, Peru: Building Capacity for Treatment and Reuse of Wastewater for Green Spaces and Urban Agriculture: A Review of the SWITCH Lima Project." SWITCH 2010. www.switchurbanwater.eu/cities/11.php. Accessed January 4, 2017.

Cavallini, Julio. "Handbook of Best Practices for the Safe and Productive Use of Domestic Wastewater." National Water Authority. April 2016.

Cavallini, Julio. "Study of Treatment Options and Residual Water Reuse in Metropolitan Lima." Lima Water. 2011. www.lima-water.de/documents/jmoscoso_informe.pdf. Accessed February 26, 2017.

Echavarria, Marta, Paola Zavala, Lorena Coronel, Tamara Montalvo, and Luz Maria Aguirre. "Green Infrastructure in the Drinking Water Sector in Latin America and the Caribbean: Trends, Challenges, and Opportunities." EcoDecisión. December 2015. www.forest-trends.org/publication_details.php?publicationID=5134. Accessed January 4, 2017.

Eisenberg, Bernd, Eva Nemcova, Rossana Poblet, and Antje Stokman. "Lima Ecological Infrastructure Strategy." Institute of Landscape Planning and Ecology. September 2014. issuu.com/ilpe/docs/lima_ecological_infrastructure_stra_9c435aba38df2f. Accessed January 4, 2017.

"Environmental Engagement in Water Residuals." The Agency for Environmental Assessment and Control (OEFA). April 2014.

"Evaluation of Small-Scale Providers of Water Supply and Sanitation Services in Peru." World Bank Water and Sanitation Program. June 2007.

Gammie, Gena, and Bert De Bievre. "Assessing Green Interventions for the Water Supply of Lima, Peru: Cost-Effectiveness, Potential Impact, and Priority Research Areas." Forest Trends. April 2015. forest-trends.org/publication_details.php?publicationID=4896. Accessed February 27, 2017.

Ioris, Antonio A.R. "The Geography of Multiple Scarcities: Urban Development and Water Problems in Lima, Peru." *Geoforum*. Vol. 43, No. 3, 2012, pp. 612–22.

Ioris, Antonio A.R. "Latin America's Large-Scale Urban Challenges: Development Failures and Public Service Inequalities in Lima, Peru." *ACME*. Vol. 14, No. 4, 2015, pp. 1161–86.

Ioris, Antonio A.R. "The Persistent Water Problems of Lima, Peru: Neoliberalism, Institutional Failures and Social Inequalities." *Singapore Journal of Tropical Geography.* Vol. 33, No. 3, 2012, pp. 335–50.

Ioris, Antonio A.R. "Water Scarcity and the Exclusionary City: The Struggle for Water Justice in Lima, Peru." *Water International*. Vol. 41, No. 1, 2016, pp. 125–39.

Karla, Nidhi Rajiv, David G. Groves, Laura Bonzanigo, Edmundo Molina Perez, Cayo Ramos, Carter J. Brandon, and Ivan Rodriguez Cabanillas. "Robust Decision-Making in the Water Sector: A Strategy for Implementing Lima's Long-Term Water Resources Master Plan." World Bank. October 14, 2015.

"Lima's Master Plan for Green Infrastructure." The Embassy of Peru in the USA. March 15, 2017. www.embassyofperu.org/headlines/2017/limas-master-plan-for-green-infrastructure. Accessed April 25, 2017.

"Master Plan of Drinking Water Supply and Sewerage Systems." SEDAPAL. June 2014.

Miranda Sara, Liliana, and Isa Baud. "Knowledge-Building in Adaptation Management: *Concertación* Processes in Transforming Lima Water and Climate Change Governance." *Environment and Urbanization*. Vol. 26, No. 2, 2014, pp. 505–24.

"National Strategy for Improvement of the Quality of Water Resources." National Water Authority. February 2016.

"Plan of the Government 2016–2021." Peruanos por el Kambio. ppk.pe/plan-de-gobierno/. Accessed March 2, 2017.

Roman, Alicia, Martina Winker, Felix Tettenborn, and Ralf Otterpohl. "Informal Settlements and Wastewater Reuse: Improve of Urban Environment and Alleviate Poverty in Lima, Peru (sic)." Institute for Wastewater Management and Water Protection, Hamburg University of Technology. November 2007.

Ruiz Rosado, A. "Urbanization, Migration and Water Management in Trujillo, Peru." *Development*. Vol. 51, No. 2, 2008, pp. 278–81.

"Strategic Institutional Plan 2011-2015." National Water Authority. 2010.

"Study Tour from Peru to Brazil on Peri-Urban Condominial Water and Sewerage Systems." World Bank. 2005.

"Study of Water Risks and Vulnerability of the Private Sector in a Context of Climate Change." Aquafondo. November 2016.

"Thirsty Lima Uses Robust Planning to Address Its Future Water Needs." World Bank. October 5, 2015.

"What is Green Infrastructure?" American Rivers. www.americanrivers.org/threats-solutions/clean-water/green-infrastructure/what-is-green-infrastructure/. Accessed April 8, 2016.